Reservoir Engineering

Sound, effective reservoir engineering allows developers to optimize energy extraction from a geothermal field and extend its commercial lifetime. Research in this area, sponsored by the U.S. Department of Energy, enables geothermal plants to generate more power at a lower cost.

Managing the Reservoir

The geothermal reservoir is the entire system of fractured and permeable rocks and the hot water or steam trapped in that volume of rock. Geothermal reservoir engineering is the application of the basic principles of physics and chemistry to the engineering problems associated with the production of hot water or steam from permeable rocks within the Earth. The rock contains most of the heat energy, but the water or steam is necessary to carry the thermal energy to the surface for economic use. The long-term success and profitability of an electricity-producing geothermal project depend on how well the geothermal resource is managed. Like oil and gas reservoirs, geothermal reservoirs can be overproduced if not properly managed. Overproduction of a reservoir leads to a significant shortening of its productive lifetime and a loss of income. Almost all geothermal fields require injection of the produced water back into the reservoir to maintain pressure and productivity. A suitably designed reservoir management program, developed using appropriate reservoir-engineering methods, allows the operating company to predict future changes in pressure, temperature, production rates, and chemistry of the produced geothermal fluids. Such information is crucial for designing power plants and other facilities required for the most economic use of the resource.

The first chemical tracer test at The Geysers was conducted at NCPA's well C-11 in January 1990.

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Reservoir engineering is of major importance in geothermal development. A typical geothermal plant, capable of generating 50 megawatts, enough to satisfy the electricity needs of 50,000 people, will cost around $40 million to design and build. The exploration and field development of wells and pipelines for this 50-megawatt plant will cost about $70 million. Engineers must design a power plant based on the predicted performance of the geothermal wells and the underlying reservoir. Any unexpected change in the characteristics of the wells or produced fluids could dramatically affect the profitability of the project.

The application of reservoir engineering begins during the exploration phase of the project with the analysis of the initial geophysical measurement data that indicate a promising geothermal system, and it continues throughout the operational life of the geothermal resource. It is the reservoir engineer's task to test wells, monitor their output, design new wells, and predict the long-term performance of the reservoir and wells. This design and prediction is accomplished by studying field and operational measurement data and using computer models to project the field operation into the future. During operation of a geothermal field, the reservoir engineer will be able to compare the actual performance to the predicted performance. If necessary, the engineer can modify the management plan for the geothermal field to obtain more efficient operation.

Research Supported by the U.S. Department of Energy

The U.S. Department of Energy (DOE) is involved in a variety of research projects to improve reservoir engineering techniques. DOE research programs are advancing the instrumentation to make important measurements, the methods needed to analyze and interpret the measurements, and the technologies used in the development and long-term operation of geothermal fields.

DOE scientists are measuring and investigating the flow of steam and hot water through reservoir rocks. Steam flows at a different rate through a geothermal reservoir than does hot water, and current studies are determining the mechanism of flow and the reasons for this different rate. Researchers continue to apply advanced techniques to determining rock and reservoir properties, such as the adsorption of water on the surface of pores in reservoir rocks and the characterization of fracture patterns. Many chemical reactions between the water and the rock affect geothermal-reservoir behavior, and water chemistry can cause corrosion of power system equipment. Research designed to understand and control these chemical reactions has important implications for maintaining permeability in the reservoir and for protecting wells and surface equipment.

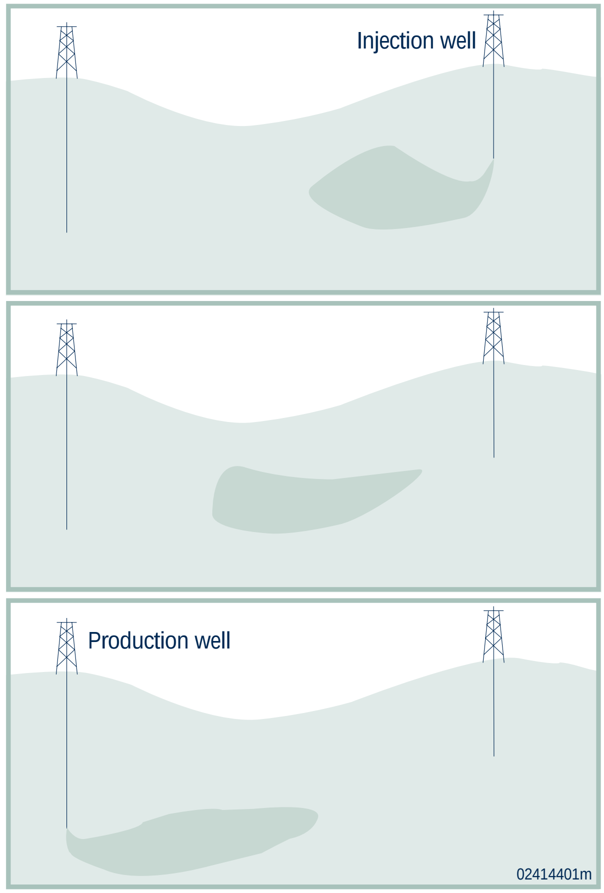
The injection of water into a geothermal reservoir must be monitored so that the pressure is maintained for production and so that cold water does not reach production wells. Program researchers are actively involved in developing a variety of chemical tracers that are injected with the cold water and follow the fluid flow paths produced with the hot water or steam. These chemical tracers must not react with the rocks or hot water, must be easily detected at very small concentrations, and must be compatible with the environment. Tracers are first tested for temperature stability in a laboratory, and then their stability is verified in active geothermal reservoirs. Measurements of the quantity of tracer produced and the time required to flow through the reservoir allow the reservoir engineer to plan the placement of injection wells and the rate of injection.

Program researchers are developing and refining numerical models for simulating geothermal reservoir performance, determining relevant physical processes, and understanding geochemical reactions. The geothermal industry uses these models to analyze and predict the influence of production rates, pressure declines, and temperature changes on the performance of the reservoir.

A widely used reservoir simulation model, TOUGH2-PC, has recently been adapted to operate on a personal computer, giving the geothermal industry greater access to a powerful modeling program. Researchers continually upgrade the versatility of reservoir simulation programs to address the needs of the reservoir engineers. The predictive capabilities of reservoir simulations are constantly improving.

The Future

The results of DOE research in geothermal reservoir engineering are helping industry develop geothermal fields more efficiently. This research is allowing industry to extend the productive life of geothermal systems and maximize the recovery of heat stored in the subsurface. Ultimately, this research will reduce the cost and increase the use of geothermal energy, an important source of clean, renewable energy.



Chemical tracer is injected via the injection well (top), passes through the reservoir, and emerges at the production well (bottom). The time it takes the tracer to flow between the wells can be used to estimate the reservoir fluid volume.

For more information on geothermal technologies, call the Office of Geothermal Technologies: (202) 586-5340

or visit the Web site: http://www.eren.doe.gov/geothermal

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